

**This Page Is Inserted by IFW Operations
and is not a part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- **BLACK BORDERS**
- **TEXT CUT OFF AT TOP, BOTTOM OR SIDES**
- **FADED TEXT**
- **ILLEGIBLE TEXT**
- **SKEWED/SLANTED IMAGES**
- **COLORED PHOTOS**
- **BLACK OR VERY BLACK AND WHITE DARK PHOTOS**
- **GRAY SCALE DOCUMENTS**

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

THIS PAGE BLANK (USPTO)



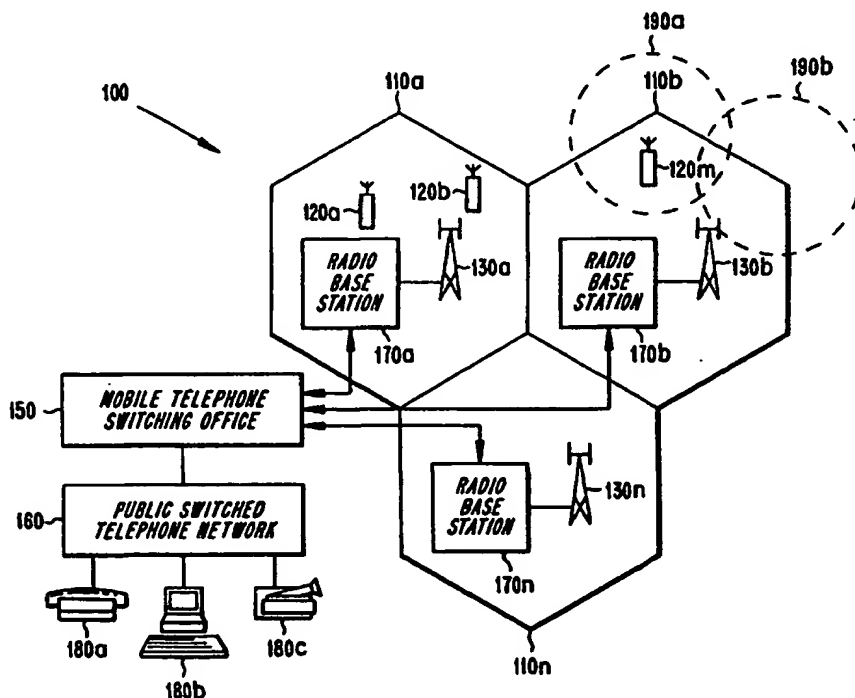
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04H 1/00, 3/00		A1	(11) International Publication Number: WO 99/26367
			(43) International Publication Date: 27 May 1999 (27.05.99)
(21) International Application Number: PCT/SE98/01941			(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 27 October 1998 (27.10.98)			
(30) Priority Data: 08/968,122 17 November 1997 (17.11.97) US			
(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE).			
(72) Inventor: MALMGREN, Göran; Gösta Ekmansväg 5, 5 tr, S-129 35 Hägersten (SE).			
(74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S-164 80 Stockholm (SE).			Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: BROADCAST NETWORK SELECTION TECHNIQUES FOR HYBRID RADIOCOMMUNICATION SYSTEMS COMPRISING BOTH A CELLULAR COMMUNICATION SYSTEM AND A RADIO BROADCAST SYSTEM

(57) Abstract

Hybrid cellular/broadcast systems are described wherein broadcast (simulcast) techniques are used to provide high data rate, downlink radiocommunication service. Various techniques for selecting an optimal broadcast network, from a plurality of potential networks, are discussed. Parameters used in these selection techniques are estimated to reduce calculation complexity.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

-1-

BROADCAST NETWORK SELECTION TECHNIQUES FOR HYBRID RADIOCOMMUNICATION SYSTEMS COMPRISING BOTH A CELLULAR COMMUNICATION SYSTEM AND A RADIO BROADCAST SYSTEM

BACKGROUND

5 The present invention relates generally to radio communication systems and, more specifically, to methods and systems for selecting a broadcast network from which to receive data in such systems.

The cellular telephone industry has made phenomenal strides in commercial operations in the United States as well as the rest of the world. Growth in major metropolitan areas has far exceeded expectations and is rapidly outstripping system
10 capacity. If this trend continues, the effects of this industry's growth will soon reach even the smallest markets. Innovative solutions are required to meet these increasing capacity needs as well as maintain high quality service and avoid rising prices.

Throughout the world, one important step in the advancement of radio
15 communication systems is the change from analog to digital transmission. Equally significant is the choice of an effective digital transmission scheme for implementing the next generation technology. Furthermore, it is widely believed that the first generation of Personal Communication Networks (PCNs), employing low cost, pocket-sized, cordless telephones that can be carried comfortably and
20 used to make or receive calls in the home, office, street, car, etc., will be provided by, for example, cellular carriers using the next generation digital cellular system infrastructure. Important features desired in these new systems are increased traffic capacity and the ability to communicate at much higher data rates than today's systems were designed to support.

25 Currently, channel access in cellular systems is primarily achieved using Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) methods. In FDMA, a communication channel is a single radio

-2-

frequency band into which a signal's transmission power is concentrated. Signals which can interfere with a communication channel include those transmitted on adjacent channels (adjacent channel interference) and those transmitted on the same channel in other cells (co-channel interference). Interference with adjacent channels is limited by the use of band pass filters which only pass signal energy within the specified frequency band. Co-channel interference is reduced to tolerable levels by restricting channel re-use by providing a minimum separation distance between cells in which the same frequency channel is used. Thus, with each channel being assigned a different frequency, system capacity is limited by the available frequencies as well as by limitations imposed by channel reuse. FDMA was used for channel access in first generation systems such as AMPS.

In TDMA systems, a channel consists of, for example, a time slot in a periodic train of time intervals over the same frequency. Each period of time slots is called a frame. A given signal's energy is confined to one of these time slots. Adjacent channel interference is limited by the use of a time gate or other synchronization element that only passes signal energy received at the proper time. Thus, with each channel being assigned a different time slot, system capacity is limited by the available time slots as well as by limitations imposed by channel reuse as described above with respect to FDMA.

As information technologies and communication technologies continue to grow closer together, demand for high data rate support (e.g., greater than 56 kbit/s) is rapidly increasing, particularly with the advent of the Internet and the desire to transmit video information. Existing radiocommunication systems were not designed to handle such high data rates.

One type of system that is being considered to accommodate the demand for high data rates is a hybrid system in which high data rates are supported in the downlink (i.e., the base-to-mobile direction) and lower data rates are supported in the uplink (i.e., mobile- to-base direction). For example, it has been proposed that

-3-

such a hybrid system could be provided wherein cellular technology system is used to support uplink traffic channels, low data rate downlink traffic channels and control channels (uplink and downlink), while a broadcast transmission system is used to support high data rate, downlink traffic channels. In particular, the

5 broadcast system known as the Digital Audio Broadcasting system (DAB) and specified in the European Telecommunication Standard entitled "Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers", ETS 300401, February 1997, the disclosure of which is incorporated here by reference, has been proposed for use in a hybrid system to

10 support high data rate downlink channels in combination with cellular technology as specified in the pan-European standard GSM.

Broadcast systems, e.g., FM radio systems, have been used independently of cellular systems for many years. Some broadcast systems, like those designed in accordance with DAB, are also simulcast systems. In broadcasting simulcast

15 systems, unlike cellular radio systems, the same information is broadcast to remote units by several transmitters. These systems are useful for transmitting at high data rates because of their larger bandwidth as compared with cellular systems. However, in combining broadcast and cellular technologies there are many design issues to be addressed, in particular how a remote unit will be assigned to a

20 broadcast network to begin receiving information over a high data rate, downlink channel.

As is well known to those skilled in the art, conventional cellular systems such as GSM and D-AMPS use many different techniques to provide a combination of high traffic capacity and high received signal quality. For

25 example, frequency reuse is a technique which is commonly used in these systems to increase capacity. This phrase refers to reusing frequencies in cells which are separated by a distance which is sufficient (given other system design factors) so that the co-channel interference caused by simultaneous transmissions on the same

-4-

frequency does not create unacceptable received signal quality at the mobile stations.

Another technique commonly used in conventional cellular systems to assist in maintaining high received signal quality is to use the mobile stations as measurement probes that evaluate signal quality on the channels which are available for communication and provide reports to the system on the measured quality parameters. This information is then used by the cellular system in, for example, deciding which channels should be used for establishing new connections, as well as handing off existing connections from one cell to another (or even within a cell).

In conventional broadcasting/simulcasting radio systems, on the other hand, the radio network is designed wherein a single frequency is used by all transmitters in a network to transmit the same information. Thus, a remote terminal simply tunes to that frequency and listens to the transmitter or transmitters to which it is geographically closest. Therefore, unlike cellular systems, most broadcast systems have conventionally not provided any mechanism for a remote station to select the network to which it will listen for downlink data.

However, one FM broadcasting system (which includes a Radio Data Service (RDS feature)) does provide a mechanism to change to an alternative frequency when the receiver experiences poor received signal quality. In this system, the receiver simply switches to a predetermined frequency with the expectation that it will continue to receive the same broadcast information with better received signal quality. The receiver does not measure to identify a particular frequency for the switch nor does it know if the alternative frequency will in fact provide acceptable received signal quality before the switch. Thus, receivers operating in accordance with RDS may experience a "ping-pong" effect as they switch back and forth between the two alternate frequencies until one of the frequencies provides adequate received signal quality.

-5-

In the proposed hybrid system described above efficient techniques for selecting a broadcast system will be important, particularly since (as shown below) the geographically closest broadcast network may not always provide the best received signal quality at the remote station. Thus, it would be desirable to provide new techniques for selecting a broadcast network that overcomes the deficiencies of conventional systems.

SUMMARY

Accordingly, it is an object of the present invention to overcome the deficiencies described above by providing techniques for selecting a broadcast network that will provide optimal downlink signal quality for a particular connection. A further object of the present invention provides techniques which enable a remote station to select one of several possible broadcast networks from which to receive information in a hybrid broadcast/cellular radiocommunication network.

A plurality of network selection techniques are described herein. These techniques use one or more of the following parameters: total power received by the remote station, power received from interfering transmitters by the remote station, useful power received by the remote station and signal-to-interference ratio, to identify an optimal broadcast network for call set-up and/or handoff.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features and advantages of the present invention will be readily apparent to one skilled in the art from the following written description, read in conjunction with the drawings, in which:

Figure 1 illustrates a hybrid cellular/broadcast radiocommunication system;
Figure 2 depicts multipath propagation in broadcast transmission systems;
Figure 3 illustrates an exemplary DAB frame structure;

-6-

Figure 4 is a block diagram representation of an OFDM transmitter architecture;

Figure 5 is a block diagram representation of an OFDM receiver architecture;

5 Figure 6 is a graph depicting a weighting function used to describe the portion of received signal power which is useful given delayed OFDM signals; and

Figure 7 illustrates simulation results for received signal quality wherein each of the six exemplary techniques for DAB network selection according to the present invention are tested and compared with a conventional technique.

10

DETAILED DESCRIPTION

In the following description, for purposes of explanation and not limitation, specific details are set forth, such as particular circuits, circuit components, techniques, etc. in order to provide a thorough understanding of the invention. For example, various details are provided relating to exemplary modulation and transmitting techniques. However it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods, devices, and circuits are omitted so as not to obscure the description of the present invention with unnecessary detail.

20

An exemplary hybrid GSM/DAB radio communication system 100 is illustrated in Figure 1. As shown therein, a geographic region served by the GSM system is subdivided into a number, n , of smaller regions of radio coverage known as cells 110a-n, each cell having associated with it a respective radio base station 170a-n which operates in accordance with the well known GSM specification.

25

Those skilled in the art will appreciate that techniques and systems according to the present invention for selecting a broadcast network can also be used

-7-

independently of such a cellular network or in a hybrid network in which the cellular portion is designed in accordance with other standards.

Each radio base station 170a-n has associated with it a plurality of transmit and receive radio antennas 130a-n. Note that the use of hexagonal-shaped cells 110a-n is employed as a graphically convenient way of illustrating areas of radio coverage associated with a particular base station 170a-n. In actuality, cells 110a-n may be irregularly shaped, overlapping, and not necessarily contiguous. Each cell 110a-n may be further subdivided into sectors according to known methods. Distributed within cells 110a-n are a plurality, m, of mobile stations 120a-m. In practical systems the number, m, of mobile stations is much greater than the number, n, of cells. Base stations 170a-n comprise *inter alia* a plurality of base station transmitters and base station receivers (not shown) which provide two-way radio communication with mobile stations 120a-m located within their respective calls. As illustrated in FIG. 1, base stations 170a-n are coupled to the mobile telephone switching office (MTSO) 150 which provides *inter alia* a connection to the public switched telephone network (PSTN) 160 and henceforth to communication devices 180a-c. The cellular concept is known to those skilled in the art and, therefore, is not further described here.

Also included in the hybrid system of Figure 1 are a plurality of DAB networks. For clarity of the figure only two DAB networks, 190a and 190b, are graphically represented by the dotted circles, although more networks may be provided as necessary to supply the desired system capacity and considering other design criteria that will be readily appreciated by those skilled in the art. Moreover, although the dotted circles shown in Figure 1 are smaller than the hexagons used to represent cells, the actual coverage area of each DAB network may, of course, be larger or smaller than that of each base station.

Unlike the cells 110a, 110b and 110c, however, each DAB network 190a and 190b will generally include a plurality of transmitters (although some DAB

-8-

networks may have only one transmitter). The DAB networks 190a and 190b will preferably operate on different frequency bands to avoid interfering with one another. However, within each network, the plurality of transmitters will broadcast the same information on the same frequency band simultaneously.

5 Thus, for example, should mobile station 120m be assigned to DAB network 190a for its downlink connection, mobile station 120m may receive data from a plurality of transmitters within DAB network 190a, depending upon various factors such as the location of the mobile station 120m, transmit power of the DAB network, etc. This concept is illustrated in Figure 2.

10 Therein, remote station 200 is receiving signals from each of four DAB transmitters 210a, 210b, 210c and 210d. Depending upon the radio propagation path between the transmitters and the remote station, the remote station may receive one or more signal rays (echoes) from each transmitter, as conceptually illustrated by the two rays shown being received from transmitter 210d. The
15 multipath propagation and signal reception associated with using a broadcast network to transmit data to the remote station is also significant as a factor in considering which network to select, as will be discussed in more detail below.

 In the exemplary embodiments described herein, DAB networks are used to provide high rate downlink data to remote stations. To foster a complete
20 understanding of techniques for selecting between broadcast networks for the purposes of, for example, initial traffic channel assignment and handoff, a basic description of DAB signal transmission is first provided, followed by exemplary receive signal quality measurements. The interested reader can find more detailed information regarding DAB signal transmissions in the above-incorporated by
25 reference ETSI standard.

 The frame structure of an exemplary DAB signal is depicted in Figure 3. Therein, it can be seen that each frame includes three fields. The first field 300 contains a synchronization (sync) word which is used by the remote unit to

-9-

synchronize to the transmitted signal. In this case, the sync word comprises two symbols. The second field 310 is the Fast Information Channel (FIC) uses n symbols to convey information regarding the current configuration of the Main Service Channel (MSC) 320. The MSC 320 contains m symbols of payload data.

5 In DAB systems, this frame structure is transmitted using several OFDM (Orthogonal Frequency Division Multiplexing) signals. In an OFDM scheme, the bandwidth is divided into a large number of orthogonal, narrowband subchannels, which are transmitted in parallel. In OFDM schemes, a high data rate data stream is modulated onto a large number of these subchannels. Although the rate of the
10 data stream is quite high, the modulation rate of each subchannel is relatively low, which makes each symbol relatively long. This, in turn, makes OFDM symbols more resistant to the effects of multipath propagation which are problematic in broadcast systems. Furthermore, an extra guard interval (an extension in time of the OFDM signal) is inserted between consecutive OFDM signals, thereby
15 reducing the effects of the delay spread even more.

The signals on different subchannels are orthogonal in the time domain, but overlap in the frequency domain. More specifically, an OFDM signal can be defined by the following equation:

$$x(t) = \sqrt{P_{tx}} \sum_{k=0}^{N-1} D_k e^{j2\pi f_k t} \quad 0 \leq t \leq T+T_g$$

20 where P_{tx} is the transmitted power, N is the number of carriers, D_k is the information on carrier k , T is the duration of a symbol and T_g is a guard interval. Thus, an OFDM signal is transmitted every $T+T_g$ second.

A block diagram representation of an OFDM transmitter which can be used to implement the present invention is illustrated in Figure 4. Therein, the high data rate data stream to be transmitted is first baseband modulated at block

-10-

400. The modulated data is then separated into the desired number of subchannels by serial-to-parallel converter 410. Each subchannel is then upconverted to its assigned radio frequency at multipliers 420. Then, each subchannel is multiplexed together to form a composite signal $x(t)$ for transmission.

5 The reverse process is applied in each remote station's receiver as illustrated in Figure 5. The received composite signal $s(t)$ is correlated to each subchannel frequency at blocks 500 and 510 to extract each subchannel from the composite signal. Then, a parallel-to-serial converter extracts the parallelized data stream at block 520. Lastly, symbol estimation is performed at block 530 to
10 decode the received information symbols. Alternative implementations of OFDM transmitters and receivers can be designed using inverse Fast-Fourier Transform and Fast-Fourier Transform techniques, respectively.

 In DAB systems, the sync field 300 in each frame is transmitted using two OFDM subchannels. One subchannel carries a NULL signal, which is used by
15 the receiver for coarse time synchronization. The second OFDM subchannel is used as a reference for demodulating the received signal which, according to this exemplary embodiment, is modulated using a differential modulation scheme, e.g., differential quadrature phase shift keying (DQPSK).

 As mentioned earlier, there are several differences between DAB radio
20 networks and conventional cellular radio networks which need to be considered when determining how to measure selection criteria for DAB networks. Specifically, the simulcasting of DAB systems creates an artificial delay spread and a remote station will experience delayed OFDM signals which may overlap the receiver's detection window thereby causing interference. When a signal is
25 substantially delayed it will not only translate into intersymbol interference (ISI), but also interchannel interference due to losses in orthogonality between subchannels. This type of interference is often referred to as self-interference, since the network itself generates its own interference. Thus, the signal-to-

-11-

interference ratio (SIR) at a receiver depends on the structure of the network configuration (i.e., the propagation delays). A measure of SIR in DAB networks can be obtained according to the following formula :

$$\Gamma^j = \frac{P_{use}^j}{P_{self}^j + P_{ext}^j + N_o} = \frac{\sum_{l=1}^{N_j} P_l^j Q(\tau_l - \tau_r)}{\sum_{l=1}^{N_j} P_l^j (1 - Q(\tau_l - \tau_r)) + P_{ext}^j + N_o}$$

under the assumption that all N_j transmitters within DAB network j are
 5 transmitting on all subchannels simultaneously. The total received power (including the slow fading) from transmitter i belonging to DAB network j is denoted P_i^j , the self interference associated with transmissions from transmitters in network j is denoted P_{self}^j and $Q()$ is a weighting function describing the fraction
 10 of the total received power that can be seen as useful due to the delayed OFDM signals. This weighting function is depicted in Figure 6. The difference between the arrived signal and the time instant that the receiver starts to detect the signal is denoted $\tau_i - \tau_r$. Interference from other DAB networks are given by P_{ext}^j and the noise level is denoted N_o .

According to the present invention, the remote station measures the
 15 received signal quality associated with each different DAB network that it can receive, or those identified for measurement over the control channel transmitted by the base station in the GSM portion of the hybrid system. This information can then be used to select one of the DAB networks to support the connection, which decision can be made either at the remote station or by the system if the quality
 20 measurements are reported. SIR is one parameter which can be estimated and used as a basis for network selection. However, according to other exemplary

-12-

embodiments, other measurements may also be used, since estimating the SIR may be unduly complex.

Six exemplary network selection schemes are described below, where DAB network j is selected out of a set of possible networks (e.g. the seven geographical closest networks). In the methods described below it is assumed that the received power is much larger than the noise floor, i.e. the noise floor, N_o , is omitted:

METHOD I

$$\arg_j \max \left\{ \sum_{i=1}^{N_j} P_i^j \right\} = j_I$$

METHOD II

$$\arg_j \max \left\{ \sum_{i=1}^{N_j} P_i^j + P_{ext}^j \right\} = \arg \max (P_{tot}^j) = j_{II}$$

METHOD III

$$\arg_j \max \left\{ \frac{\sum_{i=1}^{N_j} P_i^j}{\sum_{i=1}^{N_j} P_i^j + P_{ext}^j} \right\} = j_{III}$$

10 METHOD IV

$$\arg_j \max \left\{ \frac{\sum_{i=1}^{N_j} P_i^j}{P_{ext}^j} \right\} = j_{IV}$$

-13-

METHOD V

$$\arg \max (P_{use}^j) = j_v$$

METHOD VI

$$\arg \max (SIR^j) = j_{VI}$$

Methods I and V select the DAB network from which the terminal experiences the highest total received power and highest useful received power, respectively. Method II selects the DAB network with the highest total received power including external interference. Methods III, IV and VI are SIR-based. These methods vary in computational complexity. For example, method I only requires an estimate of P_i^j , while methods II-IV also need a further estimate of parameter P_{ext}^j . Methods V and VI add still more complexity since they require an extra estimation of the relative propagation delays ($\tau_i - t_r$) between received signals.

Applicant has simulated each of these exemplary embodiments to determine their effectiveness in selecting among DAB networks. The results of this simulation are plotted in the graph of Figure 7, which plots the cumulative distribution function (cdf) versus the signal-to-interference ratio (SIR) for each approach. The graph shows results for all six exemplary embodiments (although the graph resolution is such that the simulation results for methods I and V and III, IV and VI, respectively, essentially overlap one another) and, for comparative purposes, also plots results for a system where the terminal is always connected to the geographically closest DAB network (dotted line). Note that method II

-14-

yields relatively poor performance as compared with selecting the closest DAB network based on, but that the other techniques all provide better performance. Methods III, IV and VI (SIR based) yield the best performance.

Next, techniques according to the present invention are presented for
5 estimating the parameters needed to employ the selection criteria described above. One consideration used in creating these estimating techniques is that, for remote stations which are currently connected to the system (i.e., have been assigned a downlink traffic channel), the measurements not interfere with the reception of data. Thus, the DAB receiver does not make estimates when the FIC and MSC
10 blocks are received, except with respect to that receiver's own signal. Instead, the DAB receiver uses the time period during which the NULL signal is received to make measurements used to estimate the selection criteria. During the NULL symbol, the receiver jumps to an alternative frequency of another DAB network (a list of one or more alternative frequencies can be provided in the FIC and/or can
15 be transmitted over the control channel by the cellular portion of the hybrid system) and makes an estimate. After the NULL symbol period expires, the receiver then jumps back to the frequency on which its current DAB network is transmitting and continues to detect its data. To obtain estimates of received signal quality on its current frequency, the receiver can simultaneously detect/decode its
20 received data and apply one of the foregoing estimation schemes.

Estimation of the parameters used in the selection criteria is less complicated if the different DAB networks have synchronized transmissions. Then, several of the proposed estimation schemes use knowledge of the structure of the DAB NULL signal (symbol) to simplify the calculations. More
25 specifically, the NULL signal is a special OFDM signal which each transmitter within a DAB network only transmits on some of the subchannels. A unique pattern is assigned to each transmitter consisting of a set of subchannel pairs denoted as:

-15-

$$M_i^j = \left\{ (k_{i_1}^j, k_{i_1}^j + 1), \dots, (k_{i_m}^j, k_{i_m}^j + 1) \right\}$$

In this context a pair is two adjacent subchannels separated in frequency with $1/T$. This construction of the NULL signals, combined with a long guard interval, reduces the self-interference and the external interference between the subchannels in the NULL signal. Thus, the subchannels do not experience the SIR as
 5 described above. Instead, the received output after correlation on subchannel k can be approximated as:

$$r_{k, NULL} \cong H_{k, NULL}^i \sqrt{P_i^j} D_{k, NULL} + n_{k, NULL}$$

where $D_{k, NULL}$ is data transmitted on subchannel k , P_i^j includes all of the received powers, $H_{k, NULL}^i$ is a complex path (channel) gain including the fast fading and
 $n_{k, NULL}$ is all-white gaussian noise (AWGN). Then, for the methods described
 10 above which use P_i^j in the selection algorithm, this parameter can be estimated as:

$$P_i^j = \frac{1}{2 c(M_i^j)} \sum_{(k, k+1) \in M_i^j} (|r_{k, NULL}|^2 + |r_{k+1, NULL}|^2)$$

where $c(M_i^j)$ is the number of elements in the set M_i^j , i.e., the cardinal number of the set.

For methods described above using P_{ext}^j in the selection algorithm, the same equation can be used as for P_i^j above but for the subchannels that are transmitted
 15 by external interfering transmitters, i.e., other DAB networks. For methods described above in which P_{tot}^j is used in the selection algorithm, P_i^j and P_{ext}^j can be calculated as described to yield P_{tot}^j . However, for the receiver's current frequency band, it is possible to obtain a better estimate on the total received power by:

-16-

$$P_{tot}^f = \frac{1}{2C(\{FIC, MSC\})} \sum_{q \in \{FIC, MSC\}} \sum_{k=0}^{N-1} |x_{k,q}|^2$$

where the set {FIC, MSC} are all (or a subset) of the OFDM symbols that are not used in the sync field as shown in Figure 3.

- To obtain an estimate of the time difference $\tau_i - t_r$ used, for example, in methods V and VI described above, it is possible to utilize any known technique to estimate the difference between the time of arrival of the received signal and the time at which the receiver starts to detect the signal. For example, the channel correlation between two adjacent subchannels is often very high, with only a small phase shift which depends on the subchannel separation and $\tau_i - t_r$. This correlation can be expressed as:

$$H_{k, NULL}^i H_{k-1, NULL}^{i*} \cong |H_{k, NULL}^i|^2 e^{j2\pi(\tau_i - t_r) \Delta f_k} / T$$

- where * is complex conjugate. Thus, $\tau_i - t_r$ can be estimated as:

$$(\tau_i - t_r) = \sum_{(k, k+1) \in M_x^f} \frac{1}{2C(M_x^f)} \frac{T}{2\pi} \arg(x_{k, NULL} x_{k-1, NULL}^*)$$

The selection of a particular network can then be performed by inserting the parameters which are estimated as described above into one or more of the selection algorithms I-VI described above to determine an optimal network for providing downlink service to a remote station.

- For systems wherein the transmitters between DAB networks transmit asynchronously, there are no periods during which the remote station can safely make measurements on other DAB network frequencies without missing FIC or

-17-

the MSC data. The receiver can then not measure the useful and interfering powers as described above for insertion into the selection algorithms. However, it is possible to obtain an estimate by measuring the total received power:

$$P_{tot}^j = \frac{1}{N} \sum_{k=0}^{N-1} |r_{k,q}|^2$$

and method II can then be used.

5 Thus, methods according to the present invention enhance capacity in radio systems which also provide high data rates in the downlink. The simulation results described herein indicate that methods III, IV and VI provide very good coverage, even for very dense networks, at a rather low frequency reuse factor.

10 Estimation of the parameters used in these methods can be performed utilizing the existing DAB signal structure. Thus selection schemes according to the present invention provide the added benefit that they do not require any extra hardware and are easily implemented in software.

15 The inventive methods can be used not only for the initial setup of a connection, but also during handover procedures. For example, the estimated value on SIR is of importance to detect when it is time to make a handover. Thus, the methods discussed herein will also provide network selection schemes which can be used during handover.

20 The present invention has been described in terms of specific embodiments to facilitate understanding. The above embodiments, however, are illustrative rather than restrictive. It will be readily apparent to one skilled in the art that departures may be made from the specific embodiments shown above without departing from the central spirit and scope of the invention. Therefore, the invention should not be regarded as being limited to the above examples, but should be regarded instead as being commensurate in scope with the following
25 claims including equivalents thereof.

-18-

WHAT IS CLAIMED IS:

1. A hybrid radiocommunication system comprising:
a plurality of cellular radio transceivers for supporting data
communications with a remote station, each radio transceiver being associated
5 with a cell;
a plurality of broadcast networks for supporting downlink data
communications with said remote station, each broadcast network operating on a
different frequency and each broadcast network having at least one transmitter for
transmitting data on a respective frequency associated with that broadcast network;
10 and
means for evaluating each of said plurality of broadcast networks
and selecting one of said plurality of broadcast networks for providing said
downlink data communication with said remote station.
2. The hybrid radiocommunication system of claim 1, wherein said at
15 least one transmitter transmit signals using orthogonal frequency division
multiplexing.
3. The hybrid radiocommunication system of claim 1, wherein said
means for evaluating determines a total power received by said remote station
from each of said plurality of broadcast networks and selects a broadcast network
20 associated with a highest total received power.
4. The hybrid radiocommunication system of claim 1, wherein said
means for evaluating determines a total useful power received by said remote
station from each of said plurality of broadcast networks and selects a broadcast
network associated with a highest total useful received power.

-19-

5. The hybrid radiocommunication system of claim 3, wherein said total power includes powers associated with signals from interfering transmitters.

6. The hybrid radiocommunication system of claim 1; wherein said means for evaluating determines a signal-to-interference ratio (SIR) associated with signals received by said remote station from each of said plurality of broadcast networks and selects a broadcast network associated with a highest SIR.

7. The hybrid radiocommunication system of claim 1, wherein said means for evaluating determines a ratio of a total power received by said remote station from each of said plurality of broadcast networks to said total power plus power from interfering transmitters and selects a broadcast network associated with a highest ratio.

8. The hybrid radiocommunication system of claim 1, wherein said means for evaluating determines a ratio of a total power received by said remote station from each of said plurality of broadcast networks to power received by said remote station from interfering transmitters and selects a broadcast network associated with a highest ratio.

9. The hybrid radiocommunication system of claim 1, wherein said plurality of networks transmit synchronously.

10. The hybrid radiocommunication system of claim 9, wherein said means for evaluating takes measurements during a period when synchronization symbols are being transmitted.

-20-

11. The hybrid radiocommunication system of claim 1, wherein said plurality of networks transmit asynchronously.

12. A method for selecting one of a plurality of broadcast networks for transmitting data to a remote station comprising the steps of:

5 broadcasting data from each of said plurality of broadcast networks using orthogonal frequency division multiplexing;

 evaluating, at a remote station, each of said broadcast networks using a selection algorithm; and

 selecting one of said plurality of broadcast networks based on an
10 output of said selection algorithms.

13. The method of claim 12, wherein said step of evaluating further comprises the step of:

 determining a total power received by said remote station from each
of said plurality of broadcast networks and selecting a broadcast network
15 associated with a highest total received power.

14. The method of claim 12, wherein said step of evaluating further comprises the step of:

 determining a total useful power received by said remote station
from each of said plurality of broadcast networks and selecting a broadcast
20 network associated with a highest total useful received power.

15. The method of claim 13, wherein said total power includes powers associated with signals from interfering transmitters.

-21-

16. The method of claim 12, wherein said step of evaluating further comprises the step of:

determining a signal-to-interference ratio (SIR) associated with signals received by said remote station from each of said plurality of broadcast
5 networks and selecting a broadcast network associated with a highest SIR.

17. The method of claim 12, wherein said step of evaluating further comprises the step of:

determining a ratio of a total power received by said remote station from each of said plurality of broadcast networks to said total power plus power
10 from interfering transmitters and selecting a broadcast network associated with a highest ratio.

18. The method of claim 12, wherein said step of evaluating further comprises the step of:

determining a ratio of a total power received by said remote station from each of said plurality of broadcast networks to power received by said
15 remote station from interfering transmitters and selecting a broadcast network associated with a highest ratio.

19. The method of claim 12, further comprising the step of:

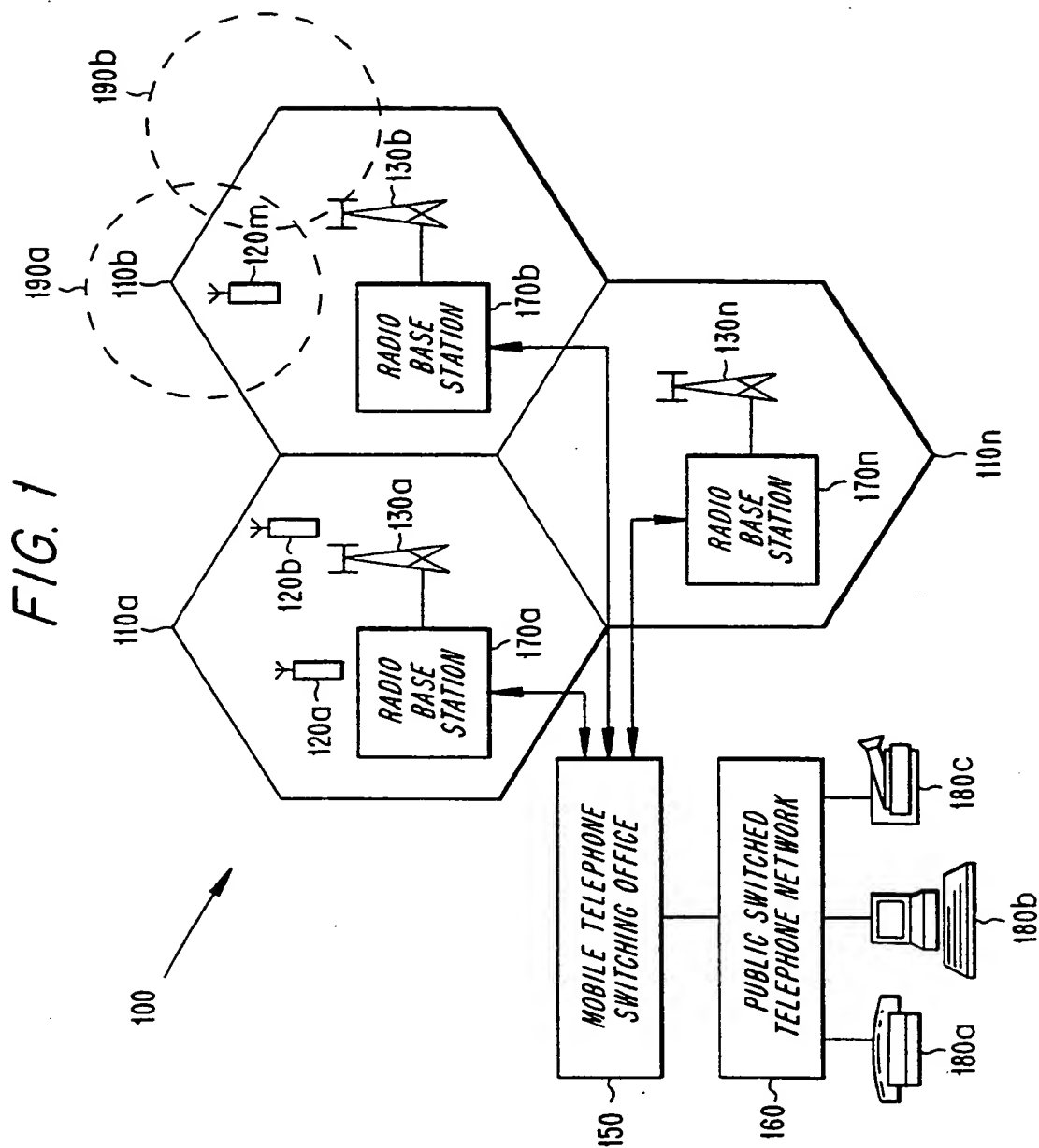
transmitting data synchronously between said plurality of broadcast
20 networks.

20. The method of claim 19, wherein said step of evaluating further comprises the step of:

making estimates of said plurality of broadcasting networks when synchronization symbols are being transmitted.

-22-

21. The method of claim 12, further comprising the step of:
transmitting data asynchronously between said plurality of
broadcast networks.



2/4
FIG. 2

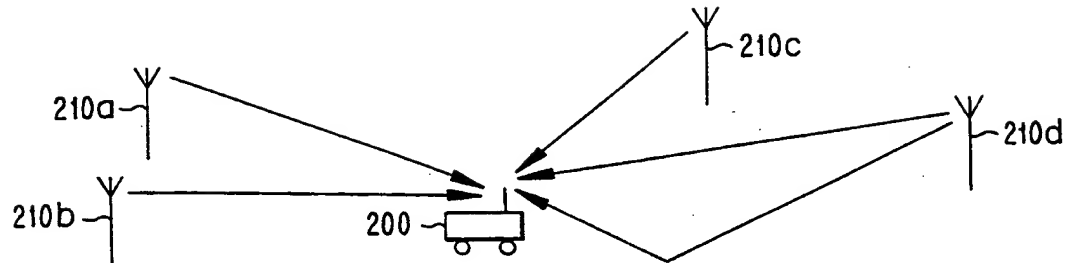


FIG. 3

300 {	310 {	320 {
<i>SYNC</i>	<i>FIC</i>	<i>MSC</i>
<hr/>		
<i>2 OFDM SYMB.</i>	<i>n OFDM SYMB.</i>	<i>m OFDM SYMB.</i>

FIG. 4

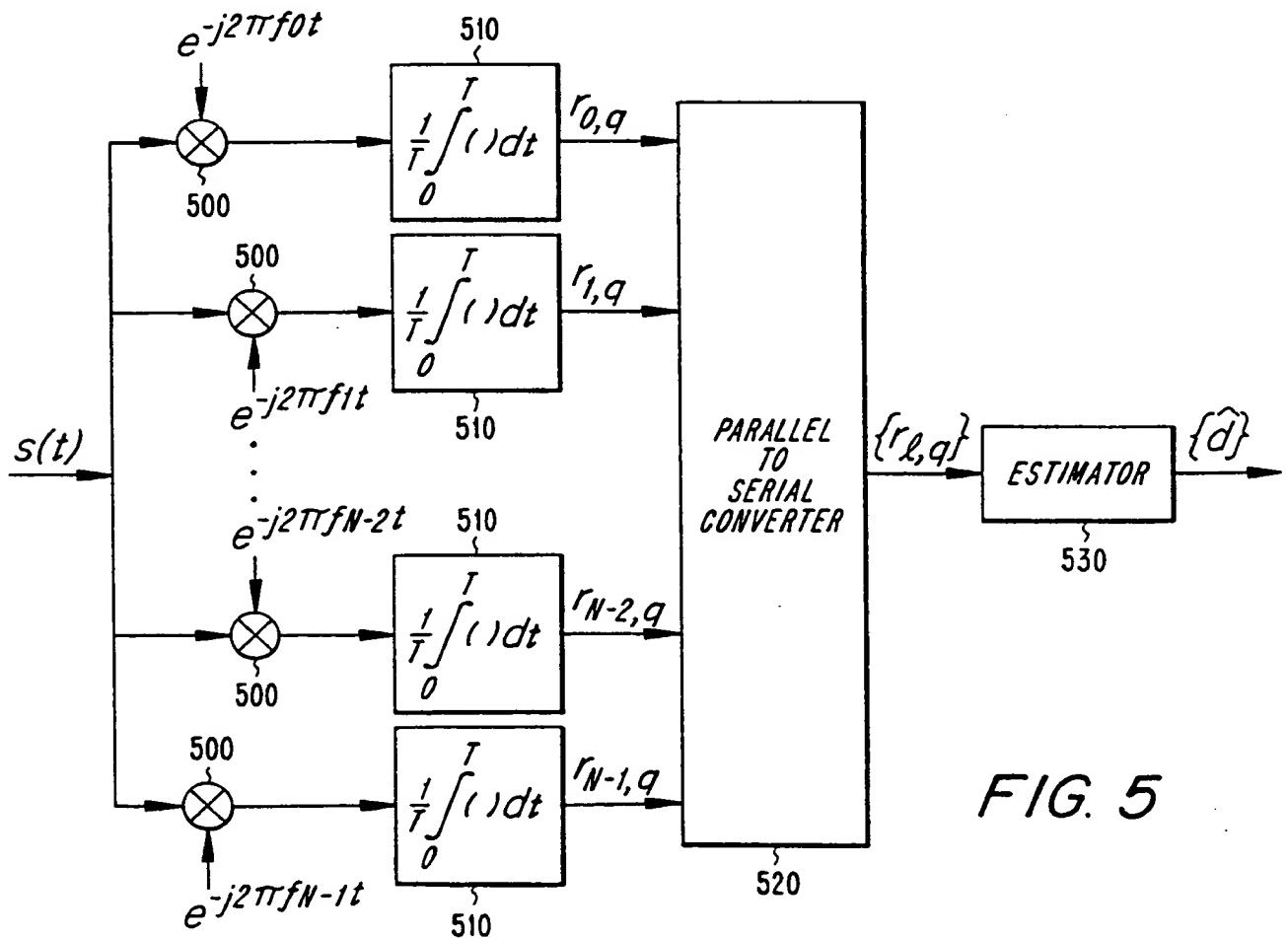
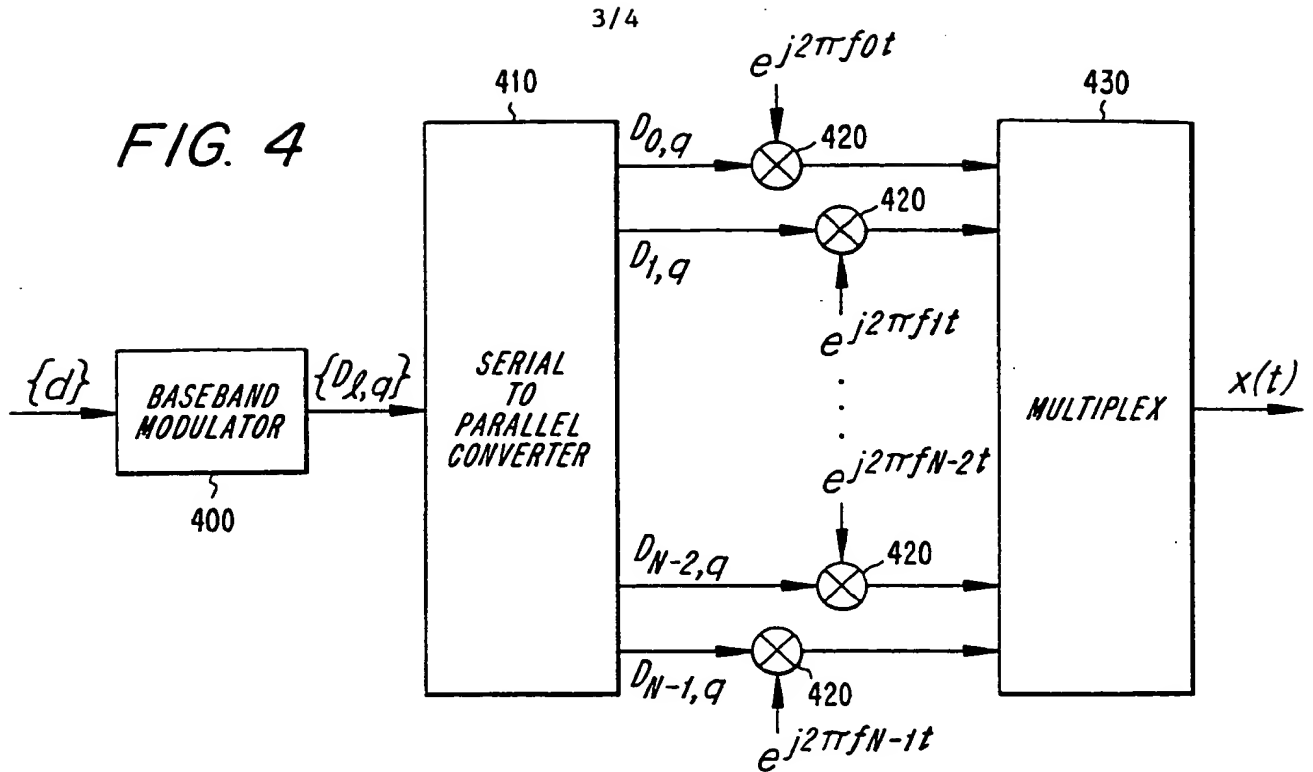


FIG. 5

FIG. 6

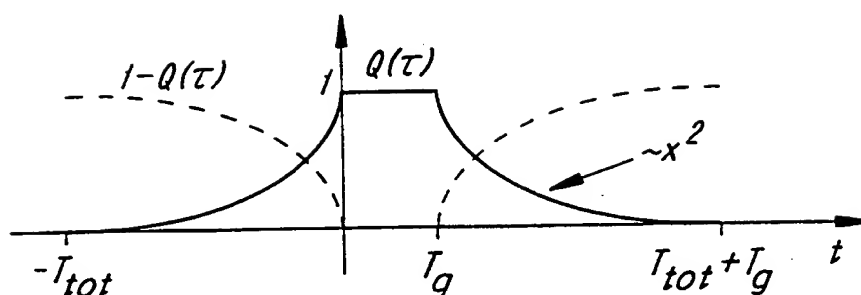
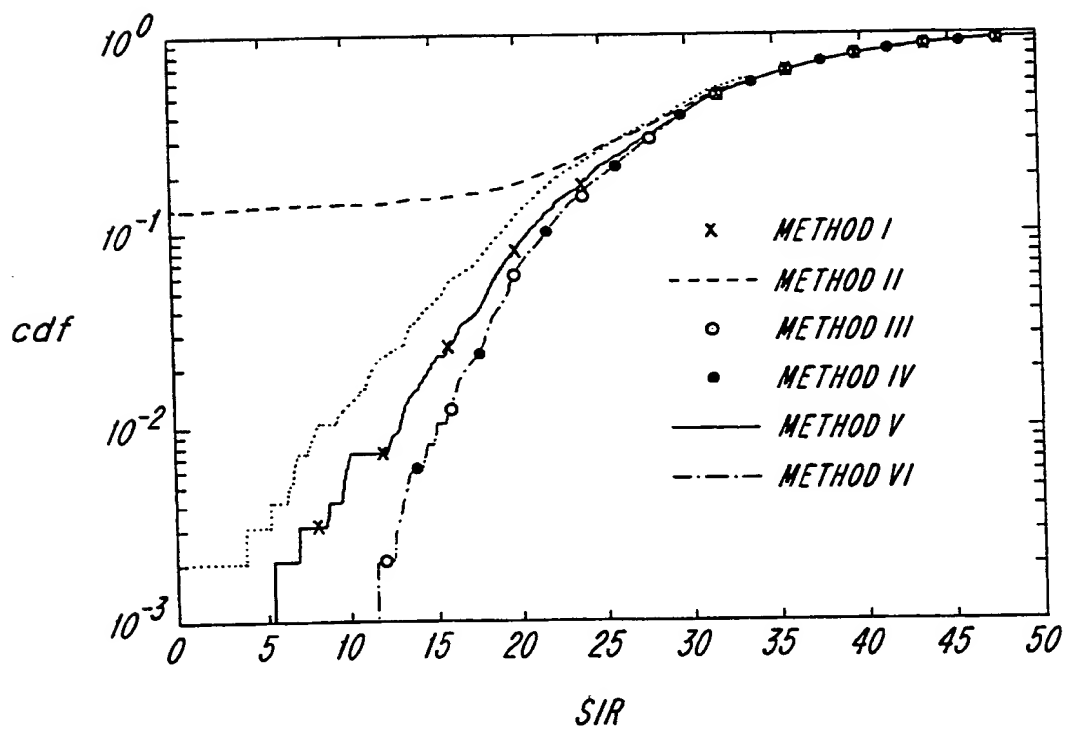


FIG. 7



INTERNATIONAL SEARCH REPORT

In. ational Application No

PCT/SE 98/01941

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04H1/00 H04H3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 15159 A (CELLULAR TELECOM LTD.) 24 April 1997 see page 1, line 1 - page 20, line 18; claims 1,37,38; figure 1 ---	1,12
A	WO 96 28904 A (BELL ATLANTIC NETWORK SERVICES, INC.) 19 September 1996 see page 10, line 6 - page 13, line 11; claim 1; figure 4 ---	1,12
A	EP 0 565 470 A (FRANCE TELECOM; TELEDIFFUSION DE FRANCE) 13 October 1993 see page 2, line 1 - page 6, line 53; claim 1; figure 1 --- -/--	1,2,12

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

24 February 1999

Date of mailing of the international search report

25/03/1999

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

De Haan, A.J.

INTERNATIONAL SEARCH REPORT

In ☐ International Application No
PCT/SE 98/01941

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 02670 A (NOKIA TELECOMMUNICATIONS OY) 23 January 1997 see page 1, line 1 - line 7; claim 1 see page 7, line 31 - page 8, line 33 ----	1,2,12
A	DE 196 30 195 A (ROBERT BOSCH GMBH) 13 November 1997 see column 1, line 1 - column 2, line 33; claim 1; figure 1 ----	1,12
A	EP 0 689 307 A (NOKIA TECHNOLOGY GMBH) 27 December 1995 see page 2, line 1 - page 3, line 40; claim 1; figures 2-4 -----	1,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/SE 98/01941

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9715159	A	24-04-1997	US 5715516 A	03-02-1998
			AU 7476796 A	07-05-1997
			CA 2234623 A	24-04-1997
			EP 0856230 A	05-08-1998
			US 5805576 A	08-09-1998
WO 9628904	A	19-09-1996	US 5651010 A	22-07-1997
			US 5729549 A	17-03-1998
			US 5822324 A	13-10-1998
			AU 5365496 A	02-10-1996
			AU 5424496 A	02-10-1996
			AU 5424696 A	02-10-1996
			AU 5424796 A	02-10-1996
			AU 5424896 A	02-10-1996
			AU 5424996 A	02-10-1996
			AU 5425096 A	02-10-1996
			AU 5425296 A	02-10-1996
			WO 9628903 A	19-09-1996
			WO 9628905 A	19-09-1996
			WO 9628906 A	19-09-1996
			WO 9628902 A	19-09-1996
			WO 9628908 A	19-09-1996
			WO 9628909 A	19-09-1996
			WO 9628910 A	19-09-1996
			US 5646942 A	08-07-1997
			US 5559808 A	24-09-1996
			US 5610916 A	11-03-1998
			US 5666365 A	09-09-1997
			US 5852612 A	22-12-1998
			US 5751707 A	12-05-1998
EP 565470	A	13-10-1993	FR 2690029 A	15-10-1993
			DE 69320861 D	15-10-1998
			US 5452288 A	19-09-1995
WO 9702670	A	23-01-1997	FI 953336 A	07-01-1997
			AU 6306796 A	05-02-1997
			EP 0882336 A	09-12-1998
DE 19630195	A	13-11-1997	WO 9742723 A	13-11-1997
			EP 0838108 A	29-04-1998
EP 0689307	A	27-12-1995	FI 942875 A	17-12-1995

THIS PAGE BLANK (USPTO)